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(54) Data compression.

(57) A method of compressing digital image or image-like pixel data. The method comprises carrying out the following steps on small blocks of pixels:

a) determining (20) the differences between digital values of adjacent pixels in the block to define respective link weights;

b) determining (21) a tree connecting all the pixels in the block such that the sum of the link weights in the tree is a minimum;

c) dividing (22) the tree into segments by removing links with weights greater than a threshold value, so dividing the block into segments of linked pixels;

d) generating a segmented representation of the block by setting the values of all pixels in each segment to a single, respective, representational value; and

e) compressing (24) the segmented representation to generate compressed data.

01	02	18	21
04	03	17	22
05	10	19	24
04	05	18	23

Fig. 1.

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DATA COMPRESSION

The invention relates to methods and apparatus for compressing digital image or image-like pixel data.

In this context image data defines the colour content of pixels of an image while image-like data defines pre or post processed (eg. filtered or compressed) image data.

Conventional electronic image generation involves the scanning of original pictures and text to generate an electronic representation of the pictures and text at a relatively high resolution. Resolutions of 300 x 300 pixels per square inch up to 1800 x 1800 pixels per square inch are common. In the case of monochrome images, each pixel is coded by a single digital value defining the grey level of that pixel, the value typically lying between zero and 255. For coloured images, each pixel is typically coded by three or four digital values which may define for example the colour components cyan, magenta, yellow and black or the components of luminance and chrominance. In all these cases, a very large amount of digital data is generated leading to problems of storage and, where the data is to be transmitted to a remote station, problems of long transmission times.

Conventionally, these problems have been reduced by applying data compression techniques to the data. An example of such a technique is run length encoding. Another technique is known as transform coding; this is able to code textures well but is not so efficient in coding sharp edges. More recently segmentation techniques have been developed that code sharp edges well, but hitherto have not performed well on smooth shading.

In accordance with one aspect of the present invention, a method of compressing digital image or image-like pixel data comprises carrying out the following steps on small blocks of pixels:

a) determining the differences between digital values of adjacent pixels in the block to define respective link weights;

b) determining a tree connecting all the pixels in the block such that the sum of the link weights in the tree is a minimum;

c) dividing the tree into segments by removing links with weights greater than a threshold value, so dividing the block into segments of linked pixels;

d) generating a segmented representation of the block by setting the values of all pixels in each segment to a single, respective, representational value; and

e) compressing the segmented representation to generate compressed data.

In accordance with a second aspect of the present invention, apparatus for compressing digital image or image-like pixel data comprises means for determining the differences between digital values of adjacent pixels in the block to define respective link weights; means for determining a tree connecting all the pixels in the block such that the sum of the link weights in the tree is a minimum; means for dividing the tree into segments by removing links with weights greater than a threshold value, so dividing the block into segments of linked pixels; means for generating a segmented representation of the block by setting the values of all pixels in each segment to a single, respective, representational value; and means for compressing the segmented representation to generate compressed data.

This new method and apparatus for analysing image data makes use of certain graph theory techniques which are described in detail in "Graph Theory for image analysis: an approach based on the shortest spanning tree" by Morris et al, IEEE proceedings, vol 133, part F, No.2, April 1986, pages 146-152. However, we have appreciated that it is not sufficient simply to apply this known technique to segment an entire image. This is because it may well be possible to construct a large path network (or tree) which connected pixels of very different type via a series of pixels in which the individual differences (or link weights) between adjacent pixels is small. For example, consider the case of a smooth vignette on a white background, the vignette smoothly varying from pure white to pure black. The straight forward application of the "shortest spanning tree" technique to this vignette will result in the shortest spanning tree extending from the pure white to the pure black joined by small links through all the different greys. If the image is divided into segments by breaking the links in the tree with weights above a threshold, the vignette and the background would all form one large segment regardless of the sharp edge between the black end of the vignette and the white background.

Recursive segmentation techniques overcome this problem by linking the two adjacent segments with the closest values starting with the original pixel values and continuing until the image is divided into the right number of segments. The segmented image not contains all the sharp edges that the original image had, but a vignette is now divided up into a series of segments.

In some cases, the values set in each segment will be sufficiently close to the real values that there is no need to store the difference or texture data since there will be little degradation.

In other cases, however, the invention further comprises generating a texture representation of the block constituted by the differences between each actual pixel value in the block and the corresponding segmented representation pixel value.

The invention uses the original 'shortest spanning tree' technique, but restricts its application to small regions or blocks of the image to avoid the problems with vignettes in extended images. The texture representation will not contain any edges in the vignetted regions, and will typically contain little but the slow gradients, and so may be easily encoded by for example transform coding. In some cases, however, the texture representation need not be compressed.

The term "tree" means a branched path that has no closed loops.

The term "small" is intended to indicate that the blocks are not only smaller than the image but also with respect to smooth features of the image.

The size of each block of pixels will be chosen empirically in practice but typically will be 8 x 8 pixels.

Typically, the representational value of a segment will be chosen to be the average of the pixel values in the segment although other values could also be used.

The compression techniques applied to the segmented and texture representations respectively are chosen to optimise the compression achieved and typically the segmented representation may be compressed using a run length or quadtree compression while the texture representation can be compressed using a threshold technique.

Another refinement, would be to have a prepass process over the image to square the edges and filter out noise before segmenting.

In a further refinement, the success of the compression achieved by a method according to the invention can be compared with other methods for compressing the block and the best chosen. For example, a method according to invention can be compared with a method involving conversion of the pixel values into the frequency domain.

Typically the processing means will comprise a suitably programmed microcomputer although the various steps could be performed by respective hardware components.

An example of a method and apparatus according to the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 illustrates the digital values making up a pixel block;

Figure 2 illustrates a shortest spanning tree for the pixel block of Figure 1;

Figure 3 illustrates the segmentation of the pixel block;

Figure 4 illustrates the pixel values in the segmented block;

Figure 5 illustrates the texture representation of the block;

Figure 6 is a block diagram of the apparatus; and,

Figure 7 is a flow diagram illustrating operation of the apparatus shown in Figure 6.

Figure 1 illustrates in diagrammatic form the digital values corresponding to a 4 x 4 pixel block. In this example, a single array of values will be considered corresponding for example to a monochrome image or a single colour separation. In practice, in the case of a coloured image, the segmenting of the block may be carried out on a single colour component and then the pixel values for each colour component will be compressed as a result of the previous determination.

The values shown in Figure 1 represent grey levels and will initially by stored in a disc store 1 (Figure 6). These values may have been generated either electronically or by scanning an original image using a conventional electronic scanning system such as the Crosfield Electronics Magnascan system. The processing of the digital values is controlled by a microprocessor 2 coupled with a data bus 3 to which the store 1 is also coupled.

Initially, the block of data values is scanned to determine the differences or link weights between each adjacent pair of pixels (step 20, Figure 7). Following that determination, a non-closed path or tree between all the pixels in the block is determined with a length defined by the sum of the link weights between adjacent pixels in the path and the path chosen being determined such that the length of the path connecting the pixels is a minimum. This path is known as the shortest spanning tree (SST) and can be determined using the techniques described in the paper mentioned above. This step is indicated as step 21 in Figure 7 and Figure 2 illustrates the SST for the pixel block shown in Figure 1. The link weights in Figure 2 are indicated by the values in brackets.

It can immediately be seen by viewing Figure 2 that an edge in the image is visible between the generally high pixel values on the right hand side of the block and the lower values on the left hand side. However, in addition to the existence of an edge there is some variation of pixel values which is not easily described by edges.

In the next step the microprocessor 2 segments the block by breaking the links above a threshold, in this case set at 8. (Step 22). This threshold will be set empirically. In this example one link has been broken and two segments created (Figure 3). The pixel values after segmentation are set to the segment average rounded to the nearest integer (A or B). In this case A = 4 and B

= 20 (Figure 4). A and B could be set to other values if appropriate. As can be seen in Figure 4, there is clear edge defined between the left and right hand segments of the block but all the fine structure is lost.

The microprocessor then determines the difference between each edge representation pixel value and the actual value of the pixel, as seen in Figure 1, to generate the texture representation as shown in Figure 5 (step 23). It will be appreciated that the sum of the pixel value pairs in Figures 4 and 5 lead to the original pixel data shown in Figure 1. The two representations are stored in respective stores 4, 5 which may be constituted by separate storage elements or different parts of a common store.

The edge representation data of Figure 4 is well suited to run length, quadtree or some other form of coding that is suitable for compacting edges and the microprocessor then carries out such a technique on the data in the store 4 (step 24). The texture representation in the store 5 is better suited to threshold coding due to the similar magnitude of the components and the microprocessor thus performs this different compression method on that data. The resultant compressed data from the stores 4, 5 is then stored in a disc store 6 (step 25).

The data can be regenerated by reversing the steps above to generate the edge and texture representations which are then summed.

Claims

1. A method of compressing digital image or image-like pixel data, the method comprising carrying out the following steps on small blocks of pixels:

a) determining (20) the differences between digital values of adjacent pixels in the block to define respective link weights;

b) determining (21) a tree connecting all the pixels in the block such that the sum of the link weights in the tree is a minimum;

c) dividing (22) the tree into segments by removing links with weights greater than a threshold value, so dividing the block into segments of linked pixels;

d) generating a segmented representation of the block by setting the values of all pixels in each segment to a single, respective, representational value; and

e) compressing (24) the segmented representation to generate compressed data.

2. A method according to claim 1, further comprising generating (23) a texture representation of the block constituted by the differences between each actual pixel value in the block and the corresponding segmented representation pixel value.

3. A method according to claim 2, further comprising compressing the texture representation.

4. A method according to claim 3, wherein the texture representation is compressed using a thresholding technique.

5. A method according to any of the preceding claims, wherein the segmented representation is compressed using a run link or quadtree compression.

6. A method according to any of the preceding claims, wherein the representational value is the average of the pixel values in the segment.

7. Apparatus for compressing digital image or image-like pixel data, the apparatus comprising means for determining (20) the differences between digital values of adjacent pixels in the block to define respective link weights; means for determining (21) a tree connecting all the pixels in the block such that the sum of the link weight in the tree is a minimum; means for dividing (22) the tree into segments by removing links with weights greater than a threshold value, so dividing the block into segments of linked pixels; means for generating a segmented representation of the block by setting the values of all pixels in each segment to a single, respective, representational value; and means for compressing (24) the segmented representation to generate compressed data.

8. Apparatus according to claim 7, further comprising means for generating (23) a texture representation of the block constituted by the differences between each actual pixel value in the block and the corresponding segmented representation pixel value.

9. Apparatus according to claim 8, further comprising means for compressing the texture representation.

01	02	18	21
04	03	17	22
05	10	19	24
04	05	18	23

Fig. 1.

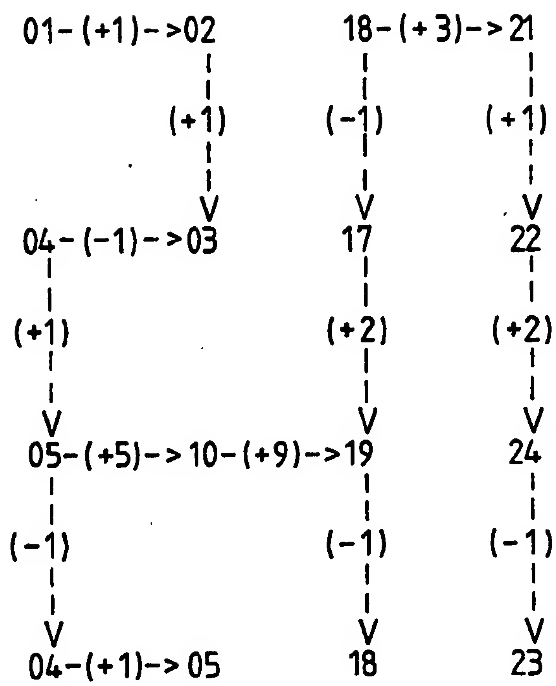


Fig. 2.

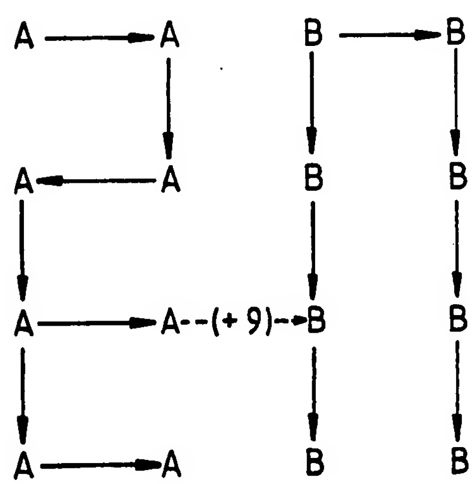


Fig. 3.

Fig.4.

4	4	20	20
4	4	20	20
4	4	20	20
4	4	20	20

Fig.5.

-3	-3	-2	1
0	-2	-3	2
1	5	-1	4
0	1	-2	3

Fig. 6.

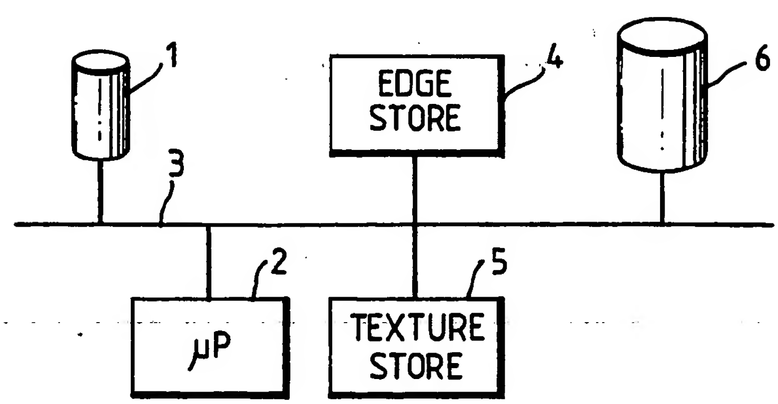
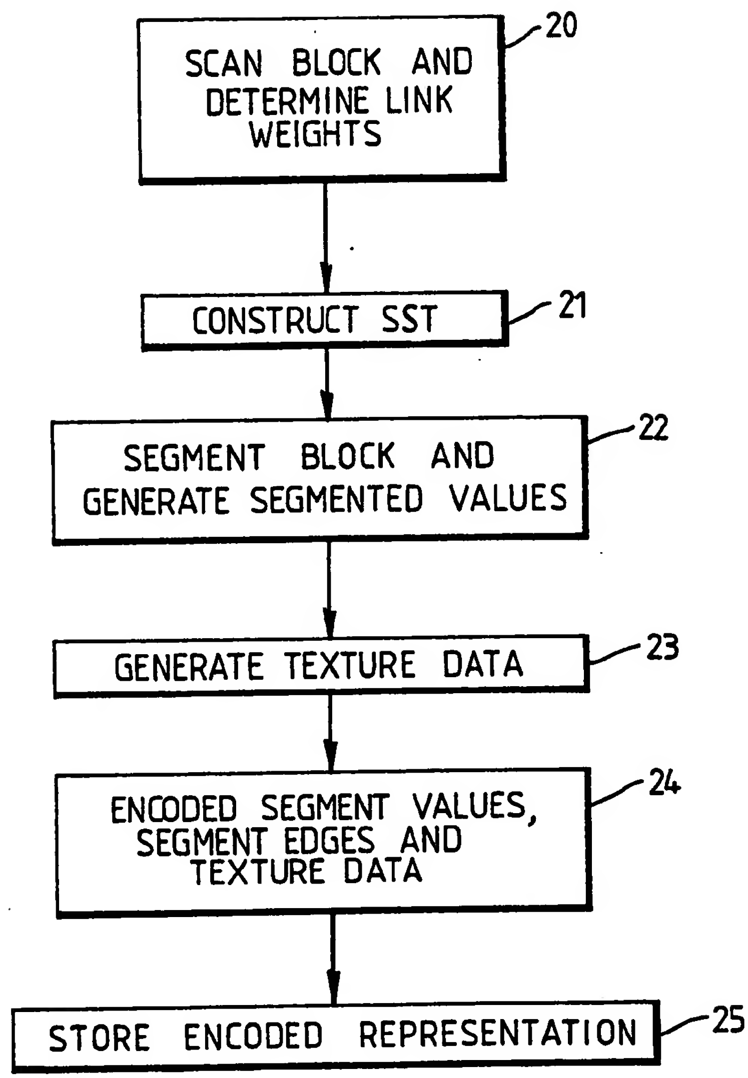


Fig. 7.


SCAN BLOCK AND DETERMINE LINK WEIGHTS
20
CONSTRUCT SST
21
SEGMENT BLOCK AND GENERATE SEGMENTED VALUES
22
GENERATE TEXTURE DATA
23
ENCODED SEGMENT VALUES, SEGMENT EDGES AND TEXTURE DATA
24
STORE ENCODED REPRESENTATION
25

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 31 1979

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	FR-A-2 262 348 (LE MATERIEL TELEPHONIQUE) * Page 2, lines 1-15; page 3, line 11 - page 5, line 25 * ---	1,7	H 04 N 1/41
D,Y	IEE PROCEEDINGS, vol. 133, no. 2, part F, April 1986, pages 146-152, Hitchin, Herts, GB; O.J. MORRIS et al.: "Graph theory for image analysis: an approach based on the shortest spanning tree" * Page 147, left-hand column, paragraph 3; page 148, left-hand column, paragraph 3.1; page 152, left-hand column, paragraph 2 * ---	1,7	
A	IEE PROCEEDINGS, vol. 130, no. 5, part F, August 1983, pages 441-451, Hitchin, Herts, GB; F D.K. MITRAKOS et al.: "Nonlinear image processing for optimum composite source coding" * Page 441, right-hand column, paragraph 3 - page 442, right-hand column, line 2; page 443, left-hand column, paragraph 2; page 446, left-hand column, paragraph 2 * ---	3,5,9	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H 04 N G 06 F
A	IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, vol. PAMI-2, no. 1, January 1980, pages 27-35, IEEE, New York, US; E. KAWAGUCHI et al.: "On a method of binary-picture representation and its application to data compression" * Page 27, paragraph I; page 28, paragraph II * -----	5	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-02-1990	DE ROECK A.F.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document